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October 1987

Project: 30.21.02
Beneficiation/Grinding Studies of Selected Minerals

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34 pp

MINERAL SCIENCES LABORATORIES
DIVISION REPORT MSL 87-138 (IR)

MICROMEDIA

SANDSTONE REDUCTION BY ATTRITOR GRINDER; PRODUCT EVALUATION AS FOUNDRY MOULDING SAND

by

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SUMMARY

Two methods of preparing sand by the reduction of 2500 μm (8 mesh) Potsdam sandstone, the first a combination of Simpson muller mixer reduction, Wemco attrition scrubbing and water washing, the second a Union attritor mill and product washing, were investigated to determine whether the latter, in particular, was superior for the production of agglomerate-free, round-grained sand specifically suitable for foundry moulding applications.

Results showed few differences in the physical characteristics of the products. Both techniques produced essentially agglomerate-free sand; however, the percentage of minus 100 μm waste fines was significantly less with the Union attritor, possibly indicating less grain fracture. Although there was some 'rounding' of the quartz grains in both test series, this was difficult to quantify.

Foundry moulding tests showed the Union attritor product to be slightly superior with regard to permeability and green compressive strength.

Keywords: Potsdam Sandstone; Reduction/Grinding; Union (Szegvari) Attritor/Simpson Mixer/Wemco Attrition; Grain Size/Shape; Foundry Evaluation.

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RÉDUCTION DU GRÈS AU MOYEN D'UN BROYEUR À ATTRITION; ÉVALUATION DU PRODUIT EN TANT QUE SABLE DE MOULAGE DE FONDERIE

par

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RÉSUMÉ

Nous avons étudié deux méthodes de préparation du sable utilisées pour réduire du grès Potsdam de 2 500 µm (8 mailles). La première de ces méthodes combinait la technique de réduction au moyen du malaxeur-broyeur Simpson, le procédé d'épuration par attrition Wemco et le lavage à l'eau. La deuxième comprenait l'utilisation d'un broyeur à attrition Union et le lavage du produit. Ces méthodes ont fait l'objet d'une étude en vue de déterminer si la deuxième, en particulier, était plus efficace pour la production d'un sable sans aggrégats, à grains ronds, convenant particulièrement comme sable de moulage de fonderie.

Les résultats n'ont indiqué que peu de différences entre les caractéristiques physiques des deux produits. Les deux techniques ont permis d'obtenir un sable essentiellement libre d'aggrégats; toutefois, le pourcentage de déchets composés de fines de moins 100 µm était beaucoup moins élevé quand le broyeur à attrition était utilisé, indiquant possiblement que la fragmentation granulaire était moindre. Bien que certains des grains de quartz aient été arrondis au cours de la série d'essais, il a été difficile de les quantifier.

Les essais de moulage en fonderie ont démontré que le produit obtenu au moyen du broyeur à attrition était légèrement supérieur en ce qui concerne la perméabilité et la résistance à vert à la compression.

Mots-clé : Grès Potsdam; réduction/broyage; broyeur à attrition Union (Szegvari)/ malaxeur Simpson/broyeur à attrition Wemco; granulométrie et forme des grains; contrôle en fonderie

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INTRODUCTION

Canada continues to import significant quantities of high-purity sand, chiefly from the United States, for use in glass manufacture and by the foundry industry. Imports in 1986, for example, were over 1 million tonnes valued at $20 million, and included 265,000 t of sand for glass manufacture, and 500,000 t of sand for use by the foundry industry.

There are a number of potential sources of high-purity silica sand in Canada, one of the more promising being the Potsdam sandstone formations of eastern Ontario and southern Quebec. Previous studies of selected samples[1,2] showed good potential for Potsdam sandstone from several areas for glass sand production; however, because of grain shape, which tends to be 'off round', sand produced from Potsdam sandstone in not a 'preferred' sand for foundry moulding purposes.

Glass sand specifications stipulate that all sand should be between 600 and 100 μm in size and have the following minimal chemical analyses: - 99.6% SiO_2, 0.03% Fe_2O_3, 0.15% Al_2O_3, with low lime and magnesia contents. Iron and steel foundry sands vary in grain size between 850 and 75 μm in closely sized ranges. AFS (American Foundryman's Society) numbers vary between 55 and 65, with the bulk of the sand preferably being on three adjacent sieves. A rounded grain shape is preferred. The quartz content should be high, 99% SiO_2, with low aluminum, iron, sodium and potassium oxides. The last three are undesirable as they act as fluxing agents.

PREVIOUS STUDIES

In processing sandstone to sand for glass and foundry applications, it is important that the parent sandstone be reduced to its natural grain size to free impurities for subsequent removal and, as well, that this be done without excessive fracturing of grains and the resulting production of unwanted fines. Whole, unfractured grains are preferred in foundry moulding, and fines are detrimental in both glass and foundry applications.

Preliminary reduction is easily achieved by jaw, cone, and roll crushers. Final reduction, to grain size, may be accomplished using one of several types of crushers/grinders, e.g., ring-roll, roller, ball or rod mills. Although normally performed dry, reduction of sandstone to grain size also may be accomplished by wet processing. In the noted previous studies, initial reduction, to 5000 μm, was by a Blake jaw crusher with a 7.5 x 15.0 cm opening and, to 1500 μm, by a 25.0 cm diameter Mine and Smelter cone crusher. Tertiary crushing, to 600 μm, was by a 12.5 x 20.0 cm double-roll, Sturtevant crusher. Further reduction to grain size was studied both dry and wet in a 45.0 cm diameter Simpson muller-mixer. An examination of the crushed products showed a good reduction of the sandstone to grain size with a minimum percentage of agglomerate and fractured grains.

Based on these initial studies, a 7-step procedure was adopted in processing the samples selected for study to ensure a maximum recovery of agglomerate-free sand with a minimum of overcrushing and resulting production of waste fines:

1. Stage-crush to 5000 μm by jaw crusher, removing minus 5000 μm by screening following each pass.

2. Remove minus 600 μm sand from jaw crusher product by Sweco screen.

3. Stage-crush minus 5000, plus 600 μm from jaw to 1500 μm by cone crusher, removing minus 1500 μm following each pass.

4. Remove minus 600 μm from cone product by Sweco screen.

5. Crush minus 1500, plus 600 μm from cone to minus 600 μm by roll crusher.

6. Combine all products and screen on Sweco at 125 μm.

7. Grind (98% solids) the plus 125 μm product from the Sweco to sand size in the Simpson muller mixer.

The Simpson muller mixer product may then be further treated by attrition scrubbing and washing, magnetic separation, flotation, leaching, etc.

Examination of products from each stage of crushing, and of the sized fractions from the Wemco attrition scrubber, showed satisfactory reduction to grain size without undue fracturing of grains and production of unwanted waste fines. Most products from the Wemco were of fairly uniform grain size with the bulk of the product (75 to 95%) being in the minus 600, plus 150 μm range. The portion of compound grains varied from 0 to 10%, with the free grains being variously described as rounded to sub-rounded to sub-angular and sharply angular, the sharply angular designation being specific to the fine, minus 100 μm sizes.

Samples of the scrubbed attrition product were submitted to the sand lab, Physical Metallurgy Research Laboratories, CANMET, for evaluation as foundry sand. Unfortunately, the small size of available samples permitted only a very limited study and further evaluation of larger samples was recommended. However, as previously noted, composite grains, non-rounded grains, and sharply angular grains tend to be generally detrimental in foundry moulding and casting practices.

During the course of these studies, samples of size-reduced Potsdam sandstone were forwarded to Union Process, Akron, Ohio, to investigate whether a better quality, more rounded grain sand, could be produced in Union's attritor scrubber/grinder through (1) - the reduction of compound grains, and (2) - the removal of interstitial, grain-attached quartz and other adhering impurities. The results showed promise and, following purchase of a Q-2 Szegvari attritor from Union Process, an in-house project was initiated to further investigate Potsdam sandstone reduction and grain shape improvement.

PRESENT STUDY

Objectives

A test program was developed to study the grinding characteristics of the Szegvari Q-2 attritor and the capability of this unit to reduce 2500 μm Potsdam sandstone to its natural grain size, nominally minus 600 μm, and to 'round off' the individual sand grains to render this sand more acceptable for foundry moulding applications.

The Szegvari Q-2 Attritor

The Szegravi Q-2 attritor, shown in Fig. 1, consists of a 10 L plastic-lined grinding tank, A, with central impeller, and a 20 L ceramic coated holding tank, B, with stirrer, the two being connected by piping containing an integrated air diaphragm pump. The system may be operated in a batch or circulatory mode as indicated in Fig. 1. For batch mode operation, the unit is filled with ceramic grinding pebbles, water added, the stirrer turned on and the sample added, step-wise, until the desired mix, (pebbles, water, sample), is achieved. Grinding is continued for 5, 10, 15

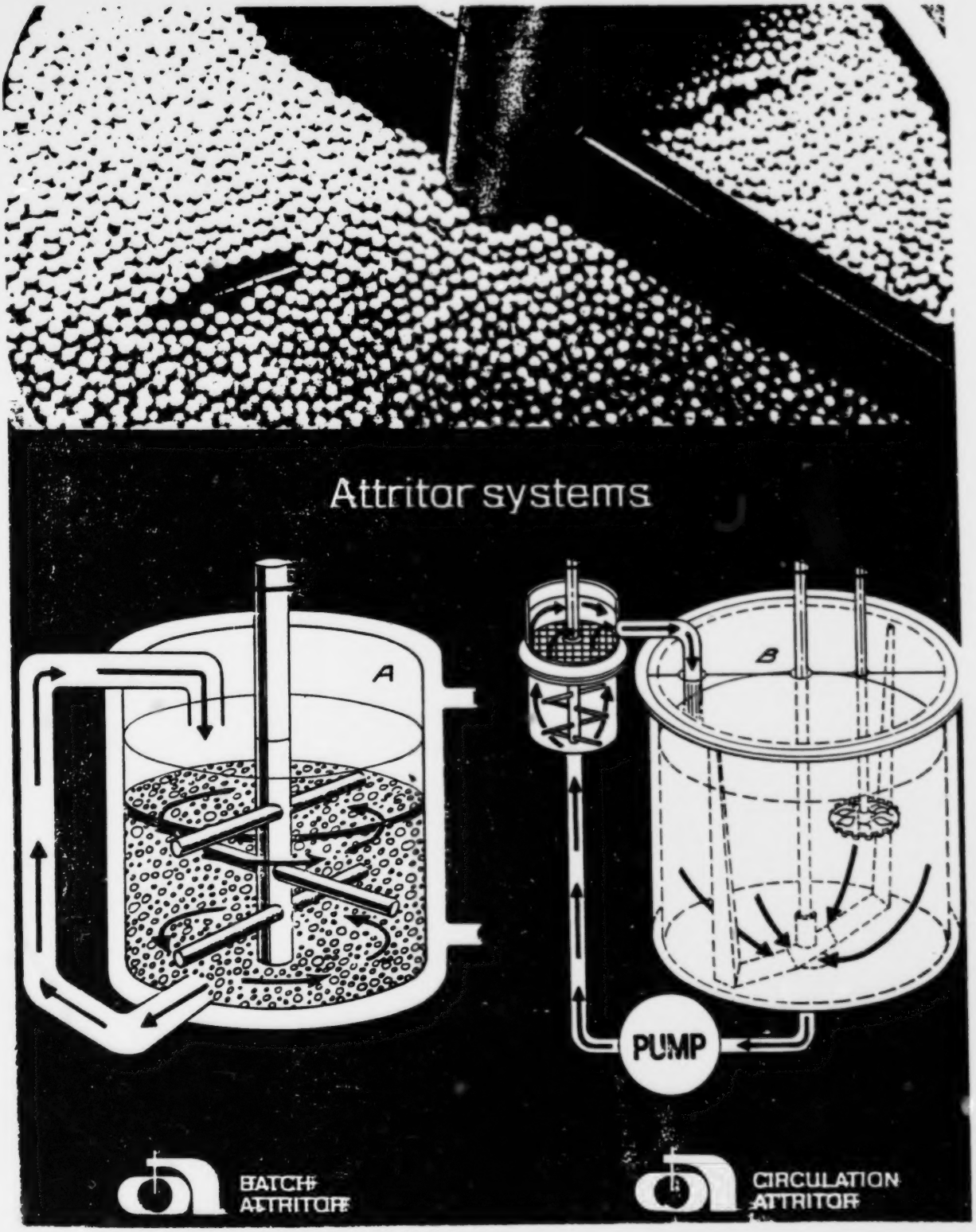

Fig. 1. The Szegvari Q-2 attritor showing batch and circulatory modes of operation

min. or for a time interval required to achieve the desired fineness of grind. The impeller is then stopped and the ground product washed through a slotted bottom discharge port. The material may also be removed through the top by tipping the grinding tank. The grinding pebbles are held in the tank during bottom discharge by the slotted grate; if discharge is via the top of the tank, then the pebbles may easily be separated from the ground product by screening.

In the circulatory grinding mode, both the grinding and holding tanks are filled with water until a satisfactory operation level is achieved, the water being pumped from the bottom of the holding tank into the bottom of the grinding tank where it overflows back into the holding tank as shown in Fig. 1(B). The material to be ground in then added, step-wise, to the holding tank until the desired mix, (pebbles, water, sample), is obtained and grinding continued until the desired level of fineness is achieved.

System variables for both batch and continuous grinding include size and volume of grinding media, particle size and volume of sample, volume of water, impeller speed, and time.

Sample Preparation

Sandstone for this current study was supplied by Wm. R. Barnes Company of Waterdown, Ont. from a quarry-site north of Kingston, Ont. Although from the Potsdam horizon, this sandstone was not of high purity; rather it was heavily iron-stained, and reddish brown in colour. Nonetheless it was deemed suitable for our purposes, namely to investigate reduction of this material to its inherent grain size and the 'rounding off' of the individual grains through attrition.

The sample was stage-reduced to 2500 μm by crushing and screening using a Blake jaw crusher with a 10 x 15 cm throat opening and a 5000 μm gap, and a 2500 μm hand screen. The crushed product was then screened on a Rotex screen to provide a minus 2500, plus 600 μm, coarse fraction: and a minus 600 μm, fine fraction, the former for subsequent study in the Union attritor and comparison with the developed Simpson muller mixer/Wemco attrition machine method for sand preparation, the latter for preliminary trial tests in the Q-2 attritor.

Q-2 Attritor: Preliminary Trial Tests (-600, +150 μm sand)

Several preliminary tests were conducted, using surplus minus 600, plus 150 μm sand, to explore the operating characteristics of the attritor before proceeding to study reduction of the minus 2500, plus 600 μm sandstone. Data for these tests (Nos. 1 to 5), shown in Table 1, indicate:

1. that smaller size grinding media, e.g., 3 mm as compared to 6 and 12 mm, produce a more finely ground product.

2. that the amount of water has a direct bearing on fineness of grind; a lower water content, within reason, results in a more finely ground product.

3. that fineness of grind increases with time; for our purposes, (reduction to sand size), a short grind, possibly only 5 min., probably would be adequate.

4. that fineness of grind is directly proportional to the impeller speed; a setting of 7 on the dial, for example, produces a more finely ground product than one of 3.5.

A number of problems were observed during Tests 1 to 5 when the attritor was operated in the circulatory mode, e.g.,

-coarse, unground feed tended to 'hang up' or settle at various locations in the system, principally in the piping below the bottom of the mixing tank, and in the attritor overflow pipe leading back to the mixing tank.

-because of the noted sand hang-up, sampling via the overflow pipe was inaccurate.

To improve this latter condition, the attritor was raised about 20 cm and the discharge pipe changed from corrugated to smooth lined hose. Secondly, the valve at the bottom of the mixing tank was removed and the pump used to empty the tank as required.

Because of obvious overgrinding, no attempt was made to compare the roundness or angularity of the sand grains. Further, it was decided to essentially restrict testwork with the minus 2500, plus 600 μm sandstone to batch mode operation.

Table 1: Preliminary Trial Tests: Feed Size -600, +150 µm (28 + 100 mesh)

Test Parameters	Test No.				
	1	2	3	4	5
Grinding Media - size (mm) - weight (kg)	 3.0 10.0	 6.0 10.0	 12.0 10.0	 6.0 10.0	 12.0 10.0
Water - (L)	14	22	22	22	22
Sand - (kg) (100%+150 µm	5.0	5.0	5.0	10.0	10.0
Impeller Speed*	7	3.5	3.5	7.0	3.5
Operating Mode	circulatory	circulatory	circulatory	circulatory	circulatory
Product Size/Time**					
% +150 µm after 15 min.	0.4	9.5	33.9	20.3	43.6
30 min.	0.02	11.0	8.5	1.1	53.8
45 min.	0.02	9.4	0.8	0.2	20.4
Rejects (g) ***	1.7	32.3	1.0	1.1	10.7

* Impeller speed as indicated by number on dial of drive

** % + 150 µm, in 15, 30 and 45 min. samples

*** Rejects refer to material remaining in the interconnecting pipes and drains and are not, in themselves, critical to this study

Q-2 Attritor: Sandstone Reduction Tests (-2500, +600 μm sandstone)

Further tests were next undertaken using minus 2500, plus 600 μm (-8 +28 mesh) sandstone to investigate both reduction to grain size and removal of interstitial cementing material, i.e., grain rounding. Data from these tests, noted in Table 2 and in Fig. 2, indicate:

(1) that batch testing using both a low feed charge and excess water tends to promote very fine grinding which, from the standpoint of glass and foundry sand production, was an undesired result.

(2) that, in batch grinding, an increase in the weight of feed, coupled with a reduction of the weight of grinding media,tends to limit the fine grinding effect and yield a coarser product.

(3) that in the circulatory mode, the least vigorous or coarsest grind was produced using excessive quantities of both water and sandstone. Although a considerable quantity of material reported in the plus 650 μm size, Test No. 6 (a), this material nonetheless was almost completely reduced to grain size.

Although all mesh fractions for products from each of the four tests were examined by binocular microscope, differences among these products were minimal. Of importance was the fact that the sandstone, in all tests, was essentially reduced to sand size, the coarser plus 630 μm fraction being no exception. Grain shape can generally be described as sub-rounded for the coarser sizes, grading to sharply angular for the finer, minus 150 μm size. This angularity of the fines is attributable, in part, to

the removal of interstitial cementing material and, in part, to overgrinding and the resulting fracture of larger quartz particles.

The large percentage of minus 150 μm material obtained in Test 6, in particular, probably was the result of extensive overgrinding and fracturing attributable to the low charge of sandstone. Fewer fines (-150 μm) were produced in Tests 6(b) and 6(c), each having a significantly larger sandstone charge.

Table 2: Sandstone Reduction Tests; Feed Size -2500, +600 µm (-8 +28 mesh)

Test Parameters	TEST No.			
	6	6(a)	6(b)	6(c)
Grinding Media				
- size (mm)	10	10	10	10
- weight (kg)	10	10	10	5
Water - (L)	4.0	22.0	2.0	2.9
Sand - (kg)	1.7	10.0	3.9	5.9
Impeller Speed*	3.5	3.5	3.5	3.5
Operating Mode	batch	circulatory	batch	batch
Product Size/Time**				
-time (min.)	5	5	5	7
µm size (%)				
+630 (46.3)***	11.3	44.0	20.1	22.1
+400 (50.2)	29.9	12.4	43.7	51.3
+315 (3.5)	10.8	11.5	11.6	10.1
+200	12.9	15.3	11.1	8.5
+150	4.1	4.0	3.4	2.0
-150	31.0	12.8	10.1	6.0
TOTAL	100.0	100.0	100.0	100.0

* Impeller speed as indicated by number on dial of drive

** % above noted size

*** Bracketted numbers denote % +630, +400, +315 µm in feed (head) sample

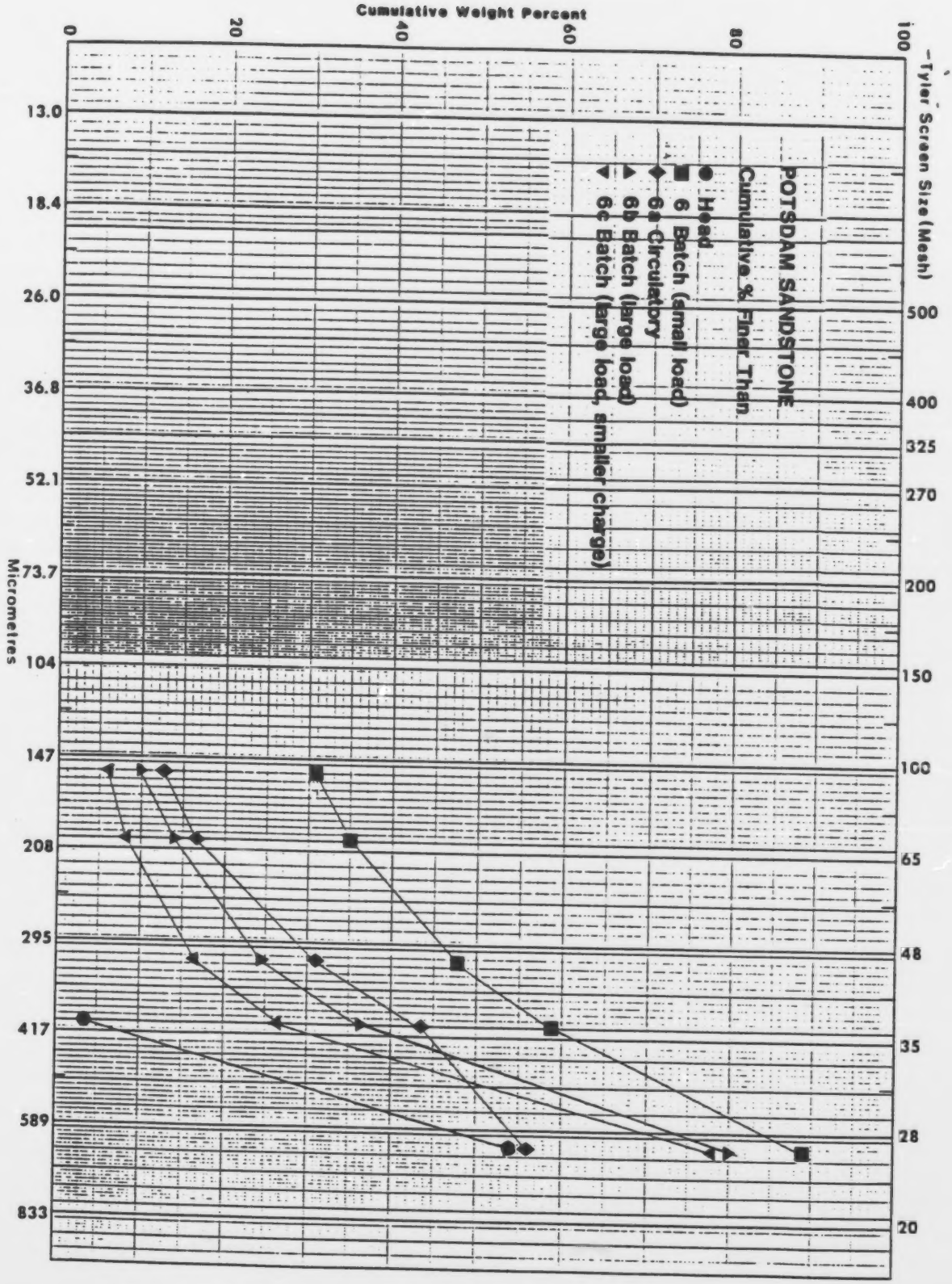

Fig. 2. Distribution curves for sandstone reduction tests

Foundry Sand Preparation

Two samples of sand, A and B, were prepared for foundry moulding tests as follows:

Sample A

Minus 2500, plus 600 μm (-8, +28 mesh) sandstone was reduced to sand in the Union attritor operated in a batch mode to provide about 10 kg of product. The product was washed and screened on 600 and 100 μm (28 and 150 mesh) sieves to provide a 10 kg sample for foundry tests. Test parameters and product size distributions are shown in Table 3 and in Fig. 3.

Sample B

Minus 2500, plus 600 μm (-8, +28 mesh) sandstone was reduced to sand in the Simpson muller mixer and scrubbed in the Wemco attrition machine. The product was then washed and screened on 600 and 100 μm (28 and 150 mesh) sieves to provide a 10 kg sample for foundry moulding tests. Test parameters and product size distributions are shown in Table 4 and in Fig. 3. The results of the above two procedures are summarized and compared in Table 5.

Table 3: Foundry Sample A, Test Parameters and Size Distribution

Test Parameters Mode: batch	Size Distributions, wt %		
	Size (μm)	Attritor Prod.	Foundry Sample*
<u>Union attritor</u> Charge: pebbles - 10kg (13 mm diam) water - 1.95 L sandstone - 3.9 k (-2500, +600 μm) Impeller: speed : 3.5 (dial) Time : 25 min. (5 runs @ 5 min.)	+600	31.0	--
	-600, +400		39.5
	-400, +300		19.7
	-300, +200	58.5	24.8
	-200, +150		6.3
	-100, +150		9.7
	-100	10.5	--
	TOTAL	100.0	100.0

* 58.5 of initial feed weight

Table 4: Foundry Sample B, Test Parameters and Size Distribution

Test Parameters Mode: batch	Size Distributions, Wt %		
	Size (μm)	Attritor Prod.	Foundry Sample*
<u>Simpson muller mixer</u>			
	+600	35.1	--
Charge: sandstone -11.5 kg (-2500, +600 μm)	-600, +400		54.9
water -0.4 L	-400, +300		19.8
Time: 30 min.	-300, +250	39.5	18.8
	-250, +150		3.3
<u>Wemco attrition machine</u>	-150, +100		3.2
Charge: sand -11.4 kg	-100	25.4	--
Water : -3.0 L	TOTAL	100.0	100.0
Time : 20 min.			

* 39.5% of initial feed weight

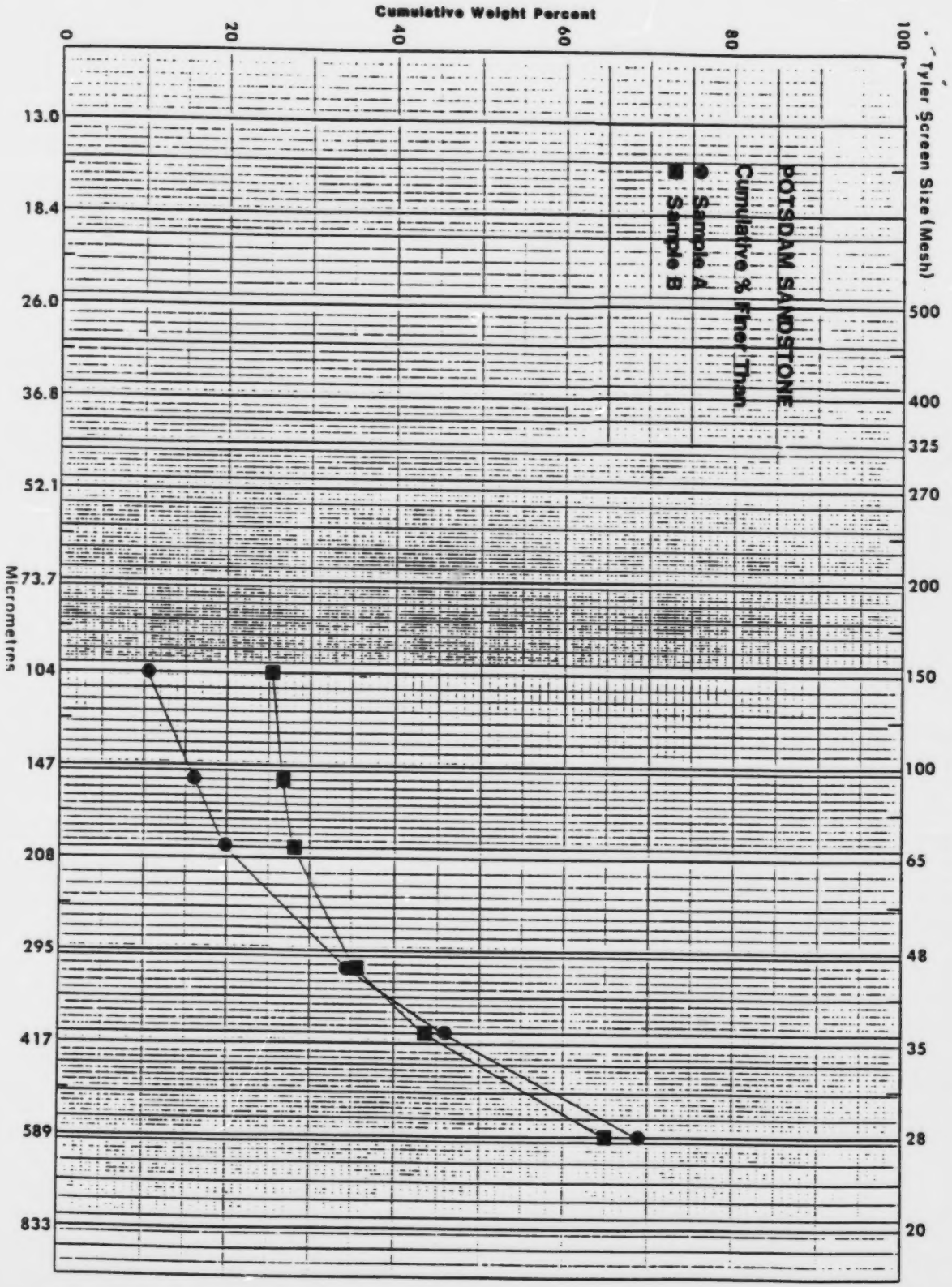

Fig. 3. Distribution curves for samples A and B

Product Comparison

An examination of the products from the A and B sample test series somewhat surprisingly showed little difference in the physical characteristics of the two. Although there appeared to be some 'rounding' of the individual quartz grains, this effect was not markedly pronounced in either product. Fewer minus 100 μm waste fines were produced with the Union attritor (10.5%) than with the Simpson muller mixer/Wemco attrition (25.4%); in addition, the rate of production of minus 600, plus 100 μm sand was substantially greater with the Union attritor (28.1 kg/hr) than with the Simpson muller/Wemco attrition (5.4 kg/hr) as noted in Table 5. Reduction of the processing time in both the Simpson muller mixer and Wemco attrition by, say, 50% conceivably is possible, thereby increasing the production rate for that process by possibly 100%. The production rate for the Union attritor possibly could be increased by doubling the feed rate or reducing processing time.

Foundry Moulding Tests*

The minus 600, plus 100 μm fraction of both A and B samples were submitted to the Sand Lab, Physical Metallurgy Research Laboratories, for foundry moulding tests. The results, compared with standard Ottawa silica sand, are shown in Table 6. These results show that sand sample A (Union attritor product) is somewhat superior to B (Simpson muller/Wemco attrition product) with respect to permeability and green compressive strength; however, both fall short of the permeability and green compressive strength shown for Ottawa sand. Unfortunately no firm conclusions can be drawn for these results relative to the suitability of either A or B for general foundry applications.

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* Moulding tests were carried out by Dr. E.I. Szabo, Foundry Section, Metals Processing Laboratory, PMRL.

Table 5: Summary and Comparision of Test Data

Products (Wt %)	Sample A Union attritor	Sample B Simpson muller/ Wemco attrition
Coarse (+600 µm)	31.0	35.1
Sand (-600, +100 µm)*	58.5	39.5
Fines	10.5	25.4
TOTAL	100.0	100.0
Processing time (min.)	25**	50***
Sand production rate (kg/hr)	28.1	5.4

Table 6: Foundry Moulding Tests

Test Parameters	Ottawa Silica	Sample A	Sample B
Sand weight (g)	2000	2000	2000
Water (mL)	30	30	30
Volclay bentonite (g)	120	120	120
Mix (min.)	5	5	5
Water (mL)	34	34	34
Mix (min.)	5	5	5
<u>Moulding Properties</u>			
Moisture w/o	3.36	3.36	3.36
Compactibility* - sample wt	63% -145 g	56% -168 g	56% -158 g
" " "	63% -145 g	55% -166 g	57% -160 g
Permeability*	126 125	240 240	320 360
Green compression* (psi)	66 67	48 50	44 38
Specimen weight* (g)	163 163	157 158	157 157

* Two determinations

CONCLUSION

The results of this study indicate that the Szegvari attritor has potential application as a one-stage secondary or tertiary crusher to substantially reduce, say, 2000 to 5000 μm Potsdam sandstone to its inherent grain size without excessive grain fracture and fines formation. Although there appears to be some 'rounding' of the individual quartz grains during grinding, this effect is difficult to quantify on the the basis of this limited test work. Results indicate that this sand has potential as foundry sand although falling somewhat short of Ottawa sand, the traditional standard of the foundry industry. No attempt was made to evaluate the degree of upgrading of this sand to glass sand quality because the sample, as received, was of relatively low grade. However, the degree of upgrading for most sands probably would be equal or superior to that achieved by the more traditional size reduction and washing procedures.

Further studies of larger, more representative samples, coupled with more detailed foundry moulding and casting tests would be prerequisites to any large-scale production of either glass or foundry sands from the Potsdam sandstone formation.

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